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GILLNET SELECTIVITY FOR FORAGE FISH WITH EMPHASIS ON MANJUBA (*Opisthonema oglinum*) IN AN ESTUARY IN THE NORTHEAST OF BRAZIL

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ABSTRACT

The selectivity of gillnets for the inhabiting forage fish community in the Santa Cruz Channel (PE, Brazil) was estimated an experiment using three mesh sizes (30, 40 and 50 mm). The SELECT was used to estimate retention curves through four models: normal location, normal scale, lognormal and gamma. Aggregated as catches in all fisheries, 28 species were identified. Selectivity parameters for species *Opisthonema oglinum*, *Anchovia clupeoides* and *Cetengraulis edentulous* were estimated. The normal scale model gave the best fit for all species studied. In the case of *O. oglinum* fishing in the Santa Cruz Channel the catches of young individuals are particularly significant in gillnets with a 30 mm mesh size. However, a possible increase in mesh size indicates little change in the length structure of the catch for larger sizes, but catches would certainly be reduced. Thus, regulations with increased mesh size should result in non-viability of fishing continuity with reduced catches.

Key words: artisanal fisheries; Clupeidae; Engraulidae; fishing management; mesh regulation.

SELETIVIDADE DE REDES DE EMALHAR PARA PEIXES FORRAGEIROS COM ÊNFASE PARA *Opisthonema oglinum* EM UM ESTUÁRIO DO NORDESTE DO BRASIL

RESUMO

As seletividades de redes de emalhar para peixes forrageiros que habitam o Canal de Santa Cruz (PE, Brasil) foram estimadas a partir de um experimento com três tamanhos de malha (30, 40 e 50 mm). O SELECT foi usado para estimar as curvas de retenção através de quatro modelos: normal com dispersão fixa, normal com dispersão variável, lognormal e gama. No total foram identificadas 28 espécies. Os parâmetros de seletividade foram estimados para as espécies *Opisthonema oglinum*, *Anchovia clupeoides* e *Cetengraulis edentulus*. O modelo normal com dispersão variável foi de melhor ajuste para todas as espécies. No caso da pesca da *O. oglinum* no Canal de Santa Cruz verificou-se que as quantidades capturadas de indivíduos jovens são particularmente mais expressivas na rede de emalhar com a malha de 30 mm. No entanto, um eventual aumento da malha indica um desvio pouco significativo da estrutura de comprimento da captura para maiores tamanhos, mas as capturas certamente seriam reduzidas. Assim, regulamentações com aumento de malha devem resultar em inviabilidade da continuidade da pesca com diminuição das capturas.

Palavras-chave: pesca artesanal; Clupeidae; Engraulidae; manejo pesqueiro; regulações de malha.

INTRODUCTION

Catches of small fish species are of great global importance, only part of them are destined for human consumption, while the largest share is used for fishmeal and fish oil production for aquaculture (TACON and METIAN, 2009). In Brazil, fishing for forage fish is practiced in estuarine zones in an artisanal way, being mainly destined for human consumption, with great commercial importance and subsistence for several fish communities in the country. One species that stands out among the main species of fish caught is the *Opisthonema oglinum*, known in Brazil as the "sardine-slab" mainly, but in the Northeast the juveniles are called "manjuba" (LESSA *et al.*, 2008).

In the state of Pernambuco, manjuba fish production is the largest among the fish, but there is an inaccuracy in the official bulletins (*e.g.* IBAMA, 2008), which aggregates several other species in this category, such as, *Cetengraulis edentulus* and *Lycengraulis grossidens*. The problem of identifying this category in the official data may have been due to the tendency of aggregating small pelagic fish that form mixed schools containing two or more species of similar size (MAES and OLLEVIER, 2002). However, for local fishermen there is no doubt concerning the definition of manjuba as *O. oglinum*, while other species, treated as incidental captures, are given other popular names (OLIVEIRA, personal observation).

Most of the capture of small species of forage fish in Pernambuco is carried out in the estuary complex of the Santa Cruz Channel (SCC), with *O. oglinum* being the main target of the fishery (IBAMA, 2008). The SCC is located in the Santa Cruz Environmental Protection Area (APA), which was created with the objective of, among other things, promoting the conservation of the natural resources available for exploration. However, there is no specific legislation for the various fishing modalities in the area. Thus, *O. oglinum* catches in the SCC are carried out without control measures with several types of fishing gear, among which gillnets (ANDRADE and SILVA, 2013) stand out. Low cost and ease of handling are advantages that contribute to the popularity of this type of fishing gear (HOVGÅRD *et al*., 1999).

The lack of legislation for the fishery of *O. oglinum* and other forager species with gill nets is partly due to the lack of studies on the operation and efficiency of the gear used. However, by their own initiative, in mid-1998, the fishermen's colony of Itapissuma promoted the replacement of nets with a mesh size of 16 mm (measured between opposing stretched nodes) by nets with a mesh size of 30 mm that were acquired with resources of the Secretary of Planning of the State of Pernambuco. The initiative, based on the empirical knowledge of fishermen, aimed at reducing the catch of young individuals. Later, ANDRADE and SILVA (2013) pointed out that catches with 25 mm and 30 mm gill nets (currently the most used) yield larger volumes compared to other gillnets. Despite the above-mentioned results there are, for example, no estimates of the relationship between the mesh size and the length format of the fish caught, including the quantification of the proportion of juveniles.

The debate about the need to protect young individuals in fisheries and about the alternatives to reach this goal is particularly important in the SCC, since the place is a nursery of several species, among them is *O. oglinum* (BARRETO and SANTANA-BARRETO, 1980), which is the target of fishing. When it is understood that there is a need for juvenile protection, establishing legal minimum length for capture is one of the most traditional and popular measures in fisheries management, because it is easy to understand and simple to use (STEWART, 2008).

The measurement of minimum size of catch is often associated with regulation of mesh size, and biological information such as length at first maturity (BEVERTON and HOLT, 1957; FROESE, 2004). However, the disproportionate catch of a length range, even of mature individuals, has been reevaluated as to its efficiency as a management measure (GARCIA *et al*., 2012). In order to reduce the adverse effects of fishing, it is necessary to estimate the frequency and productivity of the different size classes (GARCIA *et al*., 2012, LAW *et al*., 2012). Whatever the option (proportional extraction by size classes or directed to a certain phase of the life cycle), it is necessary to know the selectivity of the equipment used to implement management measures related to sizes.

Selectivity is estimated using direct or indirect methods. The direct methods are used when the size structure of the studied population is known or can be measured directly (REGIER and ROBSON, 1966). Therefore, because they demand hard-to-obtain data, direct methods are used less frequently. The indirect estimation of selectivity is done by comparing the length frequencies of the catches obtained with different mesh sizes, which can be obtained relatively easily (MILLAR and HOLST, 1997; MILLAR and FRYER, 1999).

In the SCC there are several gillnet fisheries with different mesh sizes that are used according to the target species. In the commercial drift net catches aimed at the manjuba, only the 30 mm mesh net is used, whereas this and other small forage species are treated as companion fauna in fisheries with larger meshes (*e.g.* 40 and 50 mm). The objective of this study was to estimate the selectivity of 30, 40 and 50 mm mesh networks for small pelagic forage species, with an emphasis on *O. oglinum*, which is the main target of commercial fishing conducted with the 30 mm gillnets. Evaluating the selectiveness of the mesh used in directed (30 mm) and alternative (40 and 50 mm) fishing provides important information to be considered for the management of small pelagic fishery, not only in the SCC, but also to other estuaries where similar fisheries are carried out with gillnets.

METHODS

Study area

The estuary complex Santa Cruz Channel (SCC), shared by the municipalities of Itamaracá Island, Itapissuma, Igarassu and Goiana, is the largest in the state of Pernambuco. The main channel has 22 km of length, and a width that in some stretches can reach 1.5 km (MOURA, 2009) (Figure 1). A few decades ago it was recorded that the average depth reaches 4 to 5 meters at low tide and 8 m at the center of the bed (MEDEIROS and KJERFVE, 1993).

Data collection

The experiments were carried out in October of 2013, May and September of 2014. In each opportunity, a fishing cast was carried out with an experimental net assembled with fabric of three different mesh sizes (30, 40 and 50 mm, measured between opposing stretched nodes) tied side by side, and at randomly defined geographic locations of the channel. For the experiment the nets that fishermen used regularly were used. The fabric of the nets used were nylon monofilament, with floats in the upper trunk, and plugs in the lower portion. The height of the 30 mm mesh was 2.2 m, while those with 40 and 50 mm meshes were 2.5 m.

Three different lengths of fabric for the 30 mm mesh were used (100, 150 and 200 m), while for the 40 and 50 mm meshes the fabric lengths were always the same with 200 and 250 m, respectively. The fabrics were bound in sequence (30-40-50 mm), transversely, in the canal in the October of 2013, May and September of 2014 collections which reached 550, 600 and 650 m, respectively. It is important to mention that the dimensions of the fabrics interfere more in the absolute amounts captured, but the selectivity itself remains essentially unchanged.

The nets were cast in the SCC by a local fisherman in a procedure similar to that which occurs in commercial operations, with an immersion time of one to two hours. After the casts were executed the fish were individually removed from the net and separated according to the mesh in which they were retained, and also according to the way they were trapped (Figure 2): Wedged - retained in the mesh near the dorsal fin; Gilled - retained in the position just behind the gill opening; Snagged - held in the mesh just behind the eye; Entangled - fish caught in the net by teeth, jaws, fins or other protrusions, without necessarily penetrating the mesh (KARLSEN and BJARNASON, 1987).

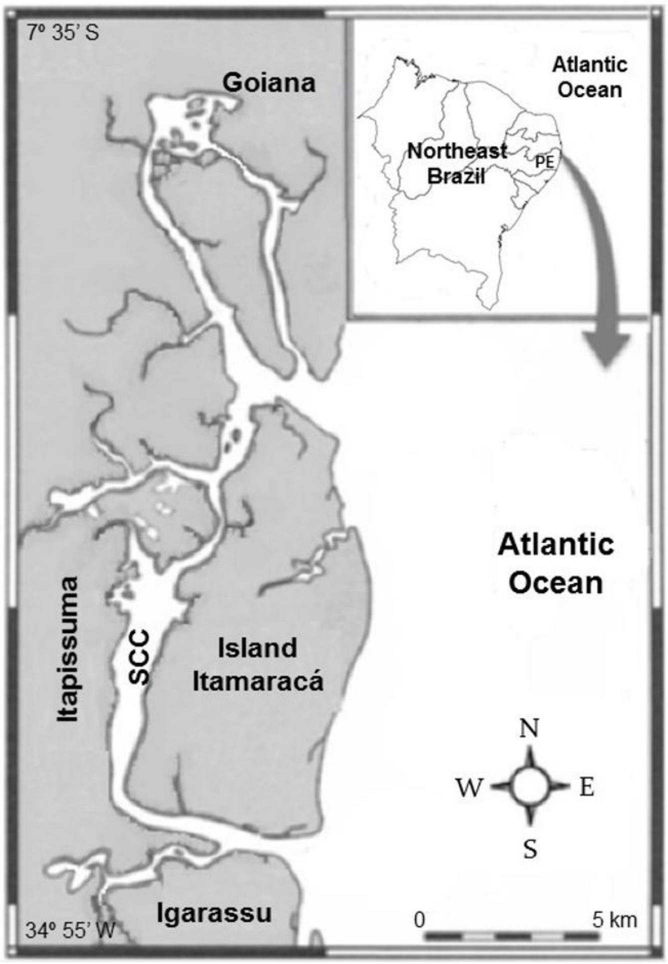

Figure 1. Study area with indication of the estuary of Santa Cruz Channel (SCC) and nearby cities (Island Itamaracá, Itapissuma, Igarassu and Goiana).

All specimens obtained in the samplings were packed in plastic bags and taken to the laboratory where they were frozen. Afterwards the specimens were identified to the species level with the aid of the taxonomic keys of FIGUEIREDO and MENEZES (1978, 1980), MENEZES and FIGUEIREDO (1980, 1985), and CARPENTER (2002a, 2002b). The standard length was measured with a 0.02 mm precision caliper.

Data analysis

Kolmogorov-Smirnov (α = 0.05) tests were performed to evaluate if there is a significant difference between the types of length frequency distribution of the fish caught with the various meshes. Subsequently, the parameters of the selectivity curves were estimated from the comparison of the length frequency distributions obtained with the different mesh sizes. The calculation code used was the SELECT described by MILLAR (1992), MILLAR and HOLST (1997), and MILLAR and FRYER (1999). The calculations are:

$$n_{lj} \sim Pois(p_j \lambda_l r_j(l)) \quad (1)$$

in which the number of fish of the length class retained in the gillnet j (n_{lj}) follows a Poisson distribution. The Poisson parameter is given by the product of the relative fishing intensity of the net j, $p_j(l)$, which is a combination of effort and power of the fishing net; of the abundance of fish of the class, l, (λ_l); and the probability of the retaining the fish of the length l class in the gillnet j, $r_j(l)$. This latter probability represents the selectivity curve. The log of the likelihood function is proportional to:

$$\sum_l \sum_j \{n_l \ \log_e[p_j \lambda_l r_j(l)] - p_j \lambda_l r_j(l)\} \quad (2)$$

The data obtained with the gillnets were evaluated with four different models for the selection curve shape: normal fixed, normal scale, lognormal, and gamma distribution (Table 1) (MILLAR, 1992; MILLAR and FRYER, 1999).

In the models shown in Table 1 k, σ, k_1, k_2, μ and α are parameters to be estimated, and m_l and m_j are the meshes of the net with the

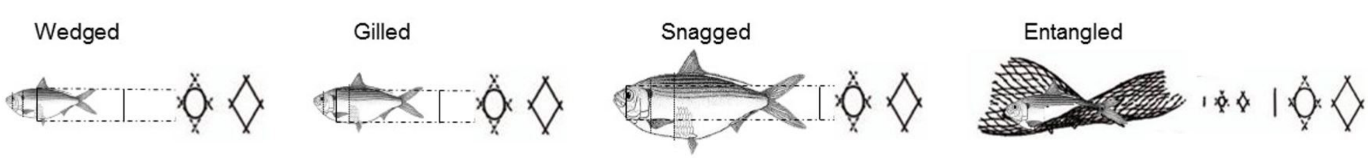

Figure 2. Four ways the fish were caught by gillnets in the Santa Cruz Channel (Figure modified of SPARRE and VENEMA, 1997).

Table 1. Models of selectivity curves.

Model	Selection curve
Normal fixed	$\exp\left(-\frac{(l-k\cdot m)^2}{2\sigma^2}\right)$
Normal scale	$\exp\left(-\frac{(l-k_1\cdot m_j)^2}{2k_2^2\cdot m_j^2}\right)$
Lognormal	$\frac{m_j}{l\cdot m_1}\exp\left\{\mu-\frac{\sigma^2}{2}-\frac{[\log(l)-\mu-\log(m_j/m_1)]^2}{2\sigma^2}\right\}$
Gamma	$\left(\frac{1}{(\alpha-1)\cdot k\cdot m_j}\right)^{\alpha-1}\exp\left(\alpha-1-\frac{1}{k\cdot m_j}\right)$

smaller mesh and of any other net with a different mesh j. Except for the standard model with fixed distribution, all the others imply that the maximum retention length and the distribution of the selection curve are proportional to the size of the mesh.

To select the appropriate model among the four considered, the deviances, which are statistics related to the likelihoods, were evaluated. The lower the deviance is, the better the fit model is. The use of deviance is justified since all models have an equal number of parameters, and it is not necessary to use information criteria. Residual analyses with graphical representations were used to evaluate the quality of fit of the selected model. All analyses of the data were performed with R program, version 3.4.2 (R CORE TEAM, 2017).

RESULTS

The number of species captured in operations with mesh sizes of 30, 40 and 50 mm were 14, 19 and 22, respectively (Table 2). A total of 28 species were identified, but only eleven (*Opisthonema oglinum, Anchovia clupeoides, Anchoa tricolor, Cetengraulis edentulus, Diapterus auratus, Diapterus rhombeus, Eucinostomus argenteus, Eucinostomus gula, Harengula clupeola, Lycengraulis grossidens and oligoplites palometa*) were captured in all three different meshes. In the meshes of 30 and 40 mm the most captured species was *O. oglinum*, whereas in the 50 mm meshes it was *D. rhombeus*.

The *O. oglinum*, *A. clupeoides* and *C. edentulus* species were selected for size evaluations because they stood out in the catches of all meshes evaluated. There was great overlap in the length of the specimens of the three species captured with the different meshes (Figure 3).

In several cases where sample sizes were not too small, there were significant differences in the comparisons of frequency distributions between different pairs of mesh sizes (Table 3). On the contrary, the equality hypothesis was not rejected in most of the comparisons when the number of individuals captured was low, which was more frequent for the 40 and 50 mm meshes as well as in the species captured incidentally.

The normal scale model was the best fit for all species analyzed (Table 4). The selectivity curves and residuals calculated with the best fit model for each species are shown in Figure 4. However, results for incidentally caught species should be viewed with a caveat, as they are based on reduced sample sizes. The standard modal lengths estimated with the models selected for the three species in the 30, 40 and 50 mm meshes were: *O. oglinum* (103.18, 137.58 and 174.97 mm), *A. clupeoides* (95.21, 126.94 and 158.68 mm) and *C. edentulus* (116.01, 154.68 and 193.35 mm).

Some of the curves shown in Figure 4 were calculated with limited data, in the sense that the captured specimens had lengths located in only one of the tails of the curves. For example, the curve for the 50 mm mesh with a mode of 174.97 mm for *O. oglinum* is an estimate, since for this species only specimens of up to slightly more than 140 mm were captured, which would correspond to the left tail of the curve. Just as for *O. oglinum*, there are also estimates of *C. edentulus* for the right tail, for longer lengths. In the case of *A. clupeoides*, the left and right (shorter and longer) estimates were made, especially for the curves calculated for the 30 and 50 mm meshes, since the majority of the captured specimens had corresponding intermediate lengths; corresponding to the highest retention range for 40 mm mesh.

Regarding the forms of retention, in the 30 mm mesh of higher frequency was generally “gilled” (Figure 5). For the 40 mm mesh importance of the “entangled” form of retention increased, in that it appeared with as much prominence as the “gilled” form. In the 50 mm mesh the “wedged” form of retention stands out the most. The percentage of retained individuals “entangled” was the lowest in the three meshes (Figure 5).

More detailed analyses were carried out for *O. oglinum* which is the target of fishing. For each of the forms of retention there is, in general, an overlap of the length classes captured with the different meshes. This appears most evident for 30 and 40 mm meshes, since the sample sizes for the 50 mm mesh are very low (Figure 6). When considering the aggregate data obtained with the three different meshes, the length frequency distribution of the “wedged” specimens retained was multimodal, whereas in the other forms of retention the configuration was unimodal (Figure 6). In the case of the “wedged” form of retention, it was found that the modal length class of the specimens retained in the 30 mm mesh was 85 to 90 mm, while in the 40 mm mesh it was 120 to 125 mm.

The average lengths of the individuals in the entangled, gilled and snagged forms of retention increased as larger mesh sizes are used (Table 5). In the 30 mm mesh, the averages of the retained lengths were, in ascending order, obtained retaining “wedged”, “gilled”, “entangled” and “snagged “. However, the order for the 40 mm mesh was “snagged “, “gilled”, “entangled” and “wedged”. There was therefore an inversion in the positioning of the “snagged” and “wedged” types, depending on the mesh used (30 or 40 mm). In the case of the 50 mm mesh, the sample size is small, but similar to that observed for the 40 mm mesh; the mean length of the “wedged” retention was greater than in the entangled type.

The normal fixed model was selected (lowest deviation) for the wedged and snagged forms of retention, while the normal scale model had the least deviation for gilled and entangled specimens (Table 6). The selectiveness and residuals calculated with these models are shown in Figure 7. The standard modal

Table 2. Species caught in the Santa Cruz Channel with gillnets of mesh size 30, 40 or 50 mm. Number of fish (n), relative frequency (RF%), range and mean of standard length.

Mesh size	Specie	n	RF%	Range (mm)	Mean (mm)
30 (mm)	*Opisthonema oglinum* (Le Sueur, 1818)	384	47.47	60.6-124.72	102.13
	Anchovia clupeoides (Swainson, 1839)	22	2.72	100.74-130.10	110.98
	Anchoa tricolor (Spix & Agassiz, 1829)	4	0.49	50.96-79.62	63.68
	Cetengraulis edentulus (Cuvier, 1829)	119	14.71	84.52-122.94	106.84
	Chloroscrombus chrysurus (Linnaeus, 1766)	3	0.37	60.38-62.78	61.63
	Dactylopterus volitans (Linnaeus, 1758)	1	0.12	107.72	107.72
	Diapterus auratus (Ranzani, 1842)	5	0.62	53.77-68.34	58.45
	Diapterus rhombeus (Cuvier, 1829)	9	1.11	55.34-102.30	70.53
	Eucinostomos argenteus (Baird & Girard, 1855)	4	0.49	57.66-74.88	68.34
	Eucinostomos gula (Quoy & Gaimard, 1824)	1	0.12	69.44	69.44
	Harengula clupeola (Cuvier, 1829)	13	1.61	84.20-99.04	92.5
	Lycengraulis grossidens (Spix & Agassiz, 1829)	241	29.79	54.92-120.40	108.8
	Oligoplistes palometa (Cuvier, 1832)	2	0.25	97.34-121.42	109.38
	Strongylura marina (Walbaum, 1792)	1	0.12	497	497
40 (mm)	*Opisthonema oglinum* (Le Sueur, 1818)	77	45.56	84.82-139.76	111.97
	Anchovia clupeoides (Swainson, 1839)	23	13.61	94.72-149.36	118.8
	Anchoa tricolor (Spix & Agassiz, 1829)	1	0.59	81.08	81.08
	Bairdiella ronchus (Cuvier, 1830)	4	2.37	119.94-137.04	127.26
	Caranx crysus (Mitchill, 1815)	1	0.59	127.56	127.56
	Cetengraulis edentulus (Cuvier, 1829)	24	14.2	86.84-130.90	115.67
	Diapterus auratus (Ranzani, 1842)	4	2.37	58.74-106.78	79.11
	Diapterus rhombeus (Cuvier, 1829)	2	1.18	103.44-105.24	104.34
	Eucinostomos argenteus (Baird & Girard, 1855)	6	3.55	75.12-114.92	96.61
	Eucinostomos gula (Quoy & Gaimard, 1824)	2	1.18	102.08-103.20	102.64
	Harengula clupeola (Cuvier, 1829)	3	1.78	104.72-116.28	111.55
	Lycengraulis grossidens (Spix & Agassiz, 1829)	4	2.37	100.32-162.92	142.65
	Mugil curema (Valenciennes, 1836)	1	0.59	162.34	162.34
	Oligoplistes palometa (Cuvier, 1832)	3	1.78	119.32-148.22	136.18
	Oligoplistes saurus (Bloch & Schneider, 1801)	4	2.37	121.50-190.70	153.19
	Pellona harroweri (Fowler, 1917)	7	4.14	100.34-114.82	105.81
	Pomadasys corvinaeformis (Steindachner, 1868)	1	0.59	112.68	112.68
	Scomberomorus brasiliensis (Collette, Russo & Zavala-Camin, 1978)	1	0.59	176.18	176.18
	*Trichiurus lepturus (*Linnaeus, 1758)	1	0.59	621	621
50 (mm)	*Opisthonema oglinum* (Le Sueur, 1818)	13	11.4	81.54-140.64	121.52
	Anchovia clupeoides (Swainson, 1839)	13	11.4	87.00-134.22	113.42
	Anchoa tricolor (Spix & Agassiz, 1829)	1	0.88	104.24	104.24
	Bairdiella ronchus (Cuvier, 1830)	8	7.02	140.02-163.72	150.45
	Caranx crysus (Mitchill, 1815)	1	0.88	154.24	154.24
	Cetengraulis edentulus (Cuvier, 1829)	10	8.77	86.72-123.44	104.59
	Centropomus undecimalis (Bloch, 1792)	1	0.88	154.44	154.44
	Dactylopterus volitans (Linnaeus, 1758)	1	0.88	118.68	118.68
	Diapterus auratus (Ranzani, 1842)	4	3.51	58.52-105.78	85.06
	Diapterus rhombeus (Cuvier, 1829)	32	28.07	79.10-131.68	91.88
	Eucinostomos argenteus (Baird & Girard, 1855)	2	1.75	81.7-92.78	87.24
	Eucinostomos gula (Quoy & Gaimard, 1824)	2	1.75	114.90-118.40	116.65
	Genidens genidens (Cuvier, 1829)	2	1.75	135.84-184.00	159.92
	Harengula clupeola (Cuvier, 1829)	2	1.75	94.12	94.12
	Lycengraulis grossidens (Spix & Agassiz, 1829)	3	2.63	118.74-227.00	162.99
	Menticicrhus americanos (Linnaeus, 1758)	1	0.88	219.94	219.94
	Mugil curema (Valenciennes, 1836)	6	5.26	181.48-219.90	196.37
	Mugil liza (Valenciennes, 1836)	1	0.88	186.5	186.5
	Oligoplistes palometa (Cuvier, 1832)	2	1.75	149.52-212.16	180.84
	Polydactyus oligodon (Günther, 1860)	1	0.88	152.44	152.44
	Pomadasys corvinaeformis (Steindachner, 1868)	7	6.14	125.20-190.72	142.15
	Pomadasys croco (Cuvier, 1830)	1	0.88	135.34	135.34

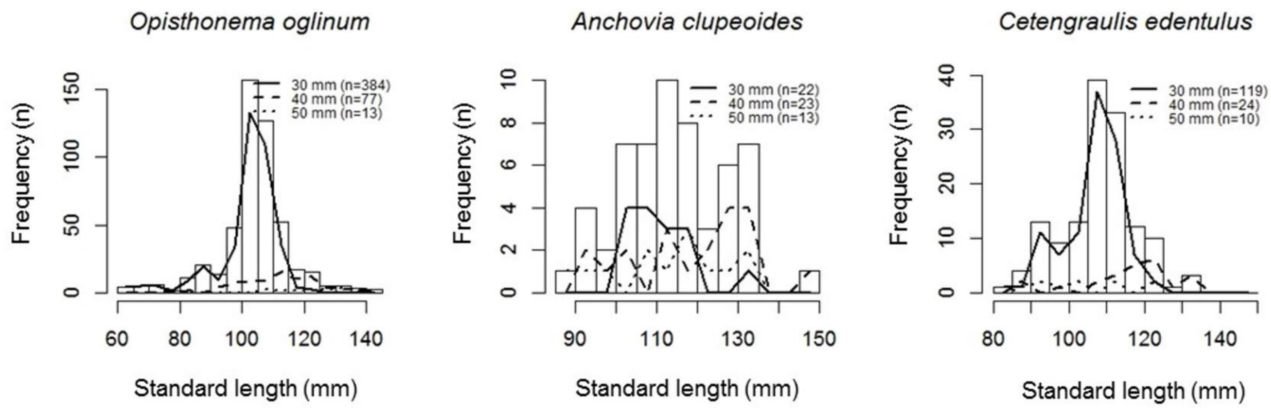

Figure 3. Size frequency of *Opisthonema oglinum*, *Anchovia clupeoides* and *Cetengrualis edentulus* caught with 30, 40 e 50 mm gillnet mesh size in the Santa Cruz Channel. Bars stand for all fish aggregated while lines stand for the number of fish caught by each mesh size.

Table 3. Kolmogorov-Smirnov p-value calculations for comparison of size frequency of *Opisthonema oglinum*, *Anchovia clupeoides* and *Cetengrualis edentulus* caught with two different meshes. The numbers of fish caught by each mesh are shown in the column titled “n”. The values inside brackets are the number of fish caught with smaller and larger meshes, respectively.

Specie	Small mesh (mm)	Larger mesh (mm)	P - value	N
Opisthonema oglinum	30	40	9.05×10^{-14}	(384; 77)
	30	50	2.18×10^{-6}	(384; 13)
	40	50	0.01	(77; 13)
Anchovia clupeoides	30	40	0.05	(22; 23)
	30	50	0.28	(22; 13)
	40	50	0.40	(23; 13)
Cetengraulis edentulus	30	40	4.80×10^{-5}	(119; 24)
	30	50	0.17	(119; 10)
	40	50	0.12	(24; 10)

Tabela 4. Parameters of the four selectivity models fitted to *Opisthonema oglinum*, *Anchovia clupeoides* and *Cetengraulis edentulus* database.

Specie	Model	Parameters	Deviance
Opisthonema oglinum	Normal fixed	(k, σ)=(3.45; 19.42)	99.85
	Normal scale	$(k1, k2)$=(3.44; 0.18)	63.43
	Lognormal	(μ, σ)=(4.67; 0.16)	84.34
	Gamma	(k, α)=(0.07; 49.25)	76.94
Anchovia clupeoides	Normal fixed	(k, σ)=(3.01; 47.65)	31.84
	Normal scale	$(k1, k2)$=(3.17; 0.94)	30.12
	Lognormal	(μ, σ)=(4.68; 0.41)	31.90
	Gamma	(k, α)=(0.41; 8.51)	31.37
Cetengraulis edentulus	Normal fixed	(k, σ)=(20.44; 325.21)	67.19
	Normal scale	$(k1, k2)$=(3.87; 0.48)	56.20
	Lognormal	(μ, σ)=(5.57; 0.43)	62.87
	Gamma	(k, α)=(0.36; 14.09)	61.64

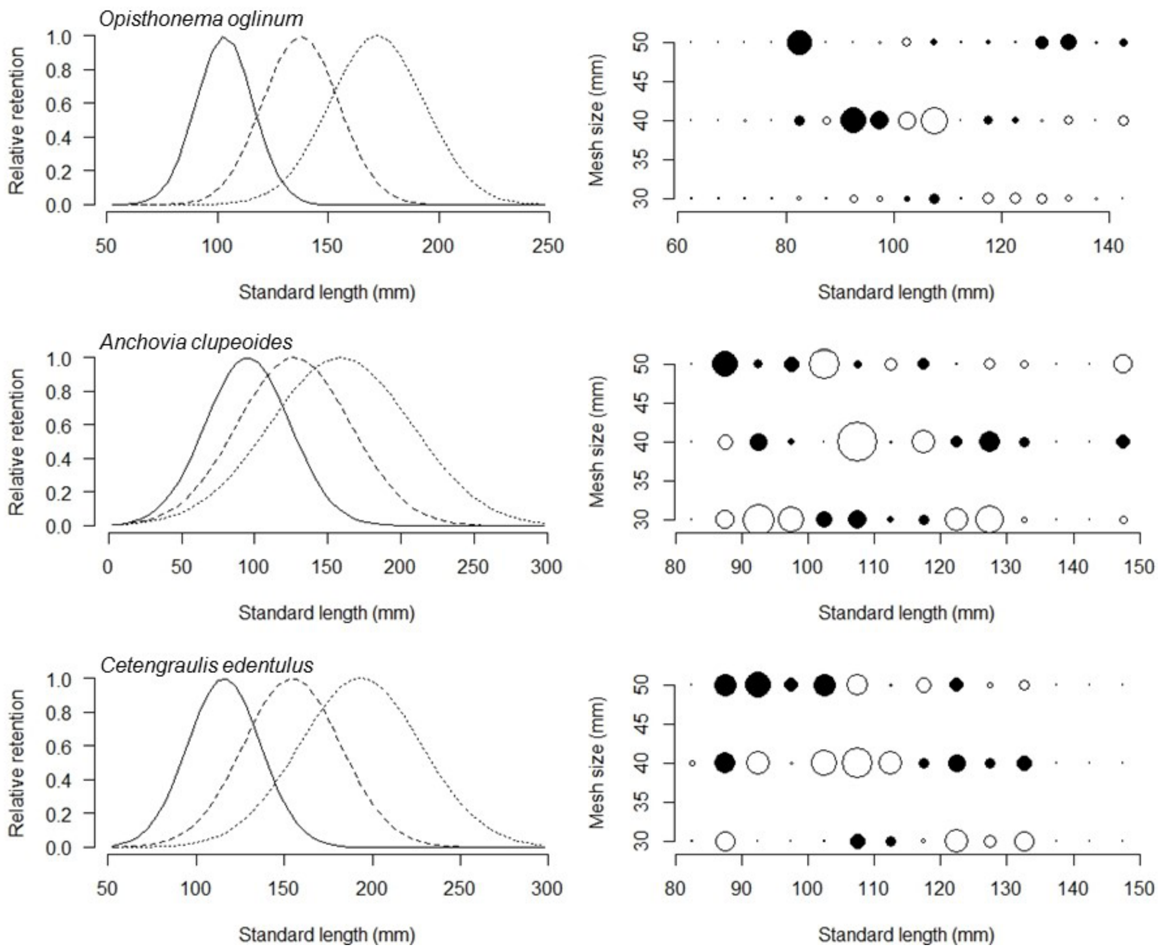

Figure 4. Selectivity curves (lines) and residuals (circles).Solid, dashed and dotted lines stand for the curves fitted to 30, 40 and 50 mm mesh databases. Filled circles stand for positive residuals, while empty ones stand for negative residuals.

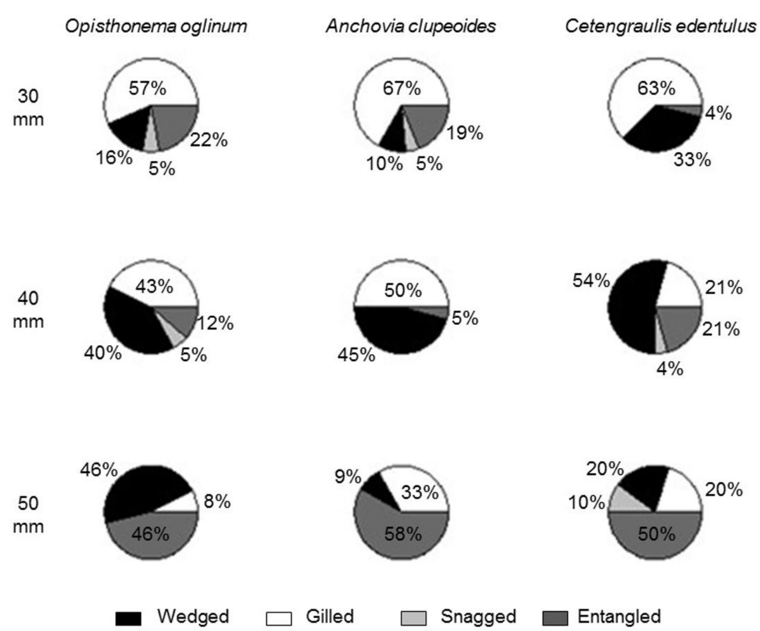

Figure 5. Ways the *Opisthonema oglinum*, *Anchovia clupeoides* and *Cetengraulis edentulus* were caught by 30 mm, 40 mm and 50 mm mesh gillnets.

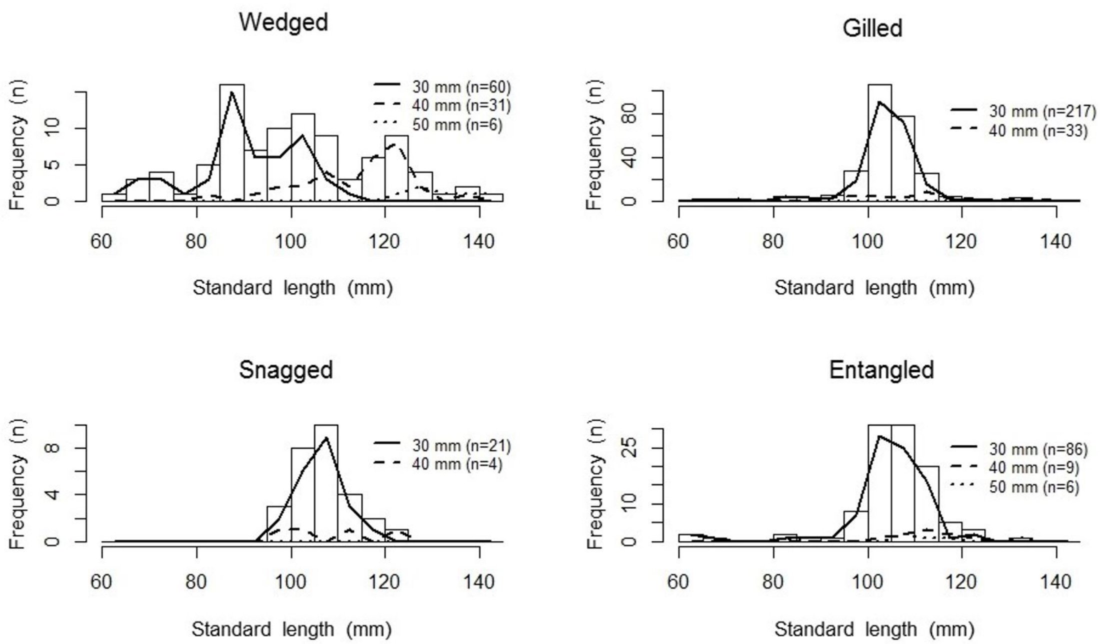

Figure 6. Size frequency distributions of fish caught by gillnets with 30, 40 and 50 mm mesh size.

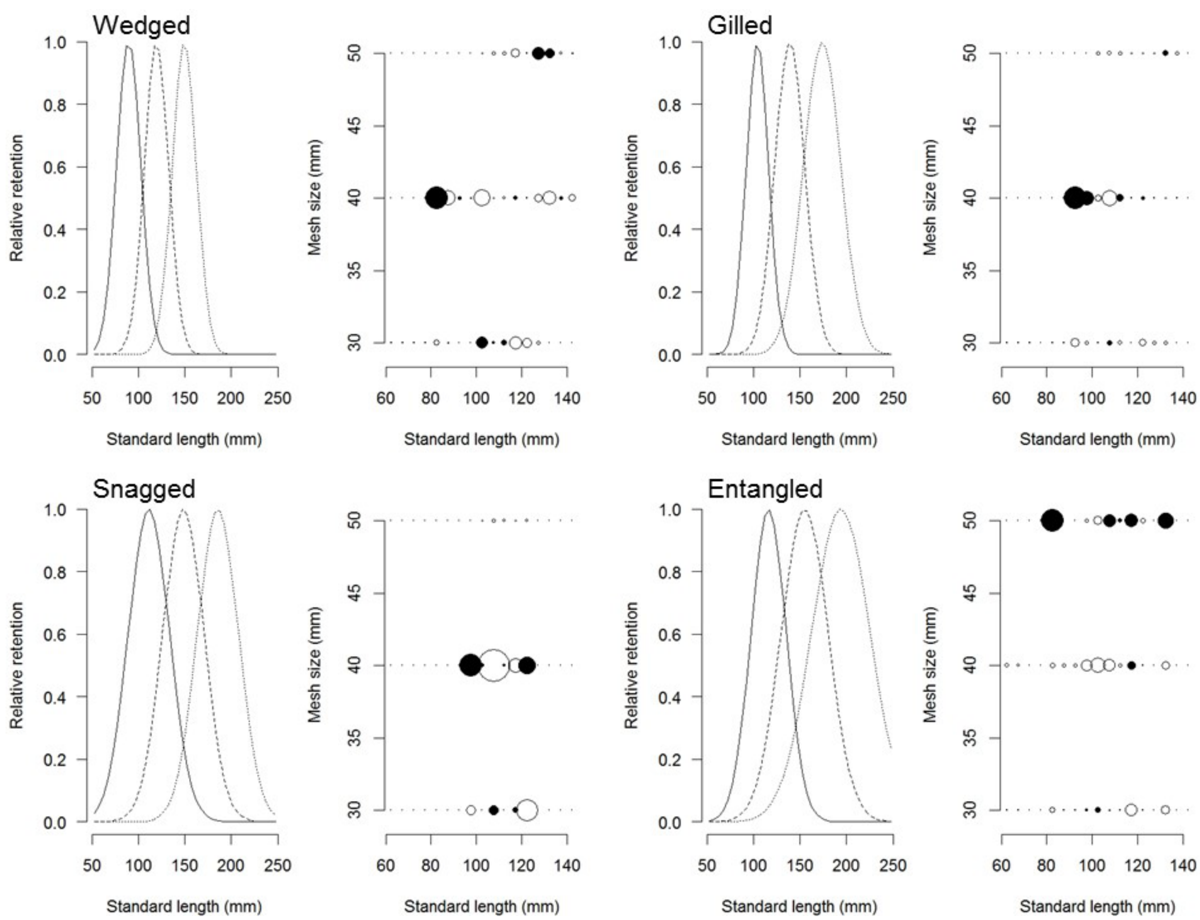

Figure 7. Selectivity curves (lines) and residuals (circles) of models fitted to *Opisthonema oglinum* database. Solid, dashed and dotted lines stand for the curves fitted to 30, 40 and 50 mm mesh databases. Filled circles stand for positive residuals, while empty ones stand for negative residuals.

Table 5. Mean lengths and standard deviations of *Opisthonema oglinum* caught by gillnet (30, 40 and 50 mm mesh sizes). ID - insufficient data.

Fish retained	30 mm	40 mm	50 mm
Wedged	90.72 ± 11.69	114.06 ± 11.41	130.90 ± 6.50
Gilled	103.50 ± 7.34	110.11 ± 11.55	ID
Snagged	106.61 ± 4.99	109.87 ± 11.45	ID
Entangled	104.47 ± 9.94	112.57 ± 6.63	110.22 ± 16.51

Table 6. Selectivity parameters estimated for *Opisthonema oglinum* caught by gillnet with 30, 40 and 50 mm mesh sizes.

Fish retained	Model	Parameters	Deviance
Wedged	Normal fixed	(k, σ)=(2.99; 12.97)	14.53
	Normal spread	$(k1, k2)$=(3.09; 0.12)	14.78
	Lognormal	(μ, σ)=(4.53; 0.12)	16.46
	Gamma	(k, α)=(0.04; 72.62)	15.67
Gilled	Normal fixed	(k, σ)=(3.46; 16.32)	42.25
	Normal spread	$(k1, k2)$=(3.48; 0.16)	38.48
	Lognormal	(μ, σ)=(4.68; 0.14)	43.72
	Gamma	(k, α)=(0.06; 58.98)	41.87
Snagged	Normal fixed	(k, σ)=(3.71; 22.12)	7.51
	Normal spread	$(k1, k2)$=(3.61; 0.23)	7.67
	Lognormal	(μ, σ)=(4.76; 0.18)	7.98
	Gamma	(k, α)=(0.09; 40.77)	7.89
Entangled	Normal fixed	(k, σ)=(14.89; 202.00)	36.64
	Normal spread	$(k1, k2)$=(3.88; 0.40)	27.60
	Lognormal	(μ, σ)=(5.46; 0.37)	30.28
	Gamma	(k, α)=(0.29; 17.46)	29.67

lengths estimated for the four forms of *O. oglinum* retention in the 30, 40 and 50 mm meshes were, respectively: wedged (89.63, 119.51 and 149.39 mm); gilled (111.33, 139.11 and 173.88 mm), snagged (111.35, 148.47 and 185.59 mm), and entangled (116.35, 155.13 and 193.91 mm). For the entangled retention form, the positive residues in the 50 mm mesh are highlighted.

DISCUSSION

Fishing carried out with gillnets in the SCC are multi-species. In cases such as these, information on the biology and interactions of many species is required for management decision-making (CAMPOS and FONSECA, 2003). Therefore, with regard to gillnet fishing in the SCC, priority is given to the development of studies on *O. oglinum*, *A. clupeoides* and *C. edentulus*, which are caught in relatively large quantities in addition to the fishing operations carried out with the three different meshes analyzed.

In this work, no differences were detected regarding the selectivity models chosen for the *O. oglinum*, *A. clupeoides* and *C. edentulous* species (normal scale) that are of the order, Clupeiformes. All the species mentioned above have laterally compressed bodies but have near fusiform shapes. Admittedly the morphology greatly affects the catchability and selectivity of fish in gillnet fisheries (REIS and PAWSON, 1999), and judging by the results available so far, for nearly fusiform formats, the normal scale seems to be the more appropriate, specific solution. The results obtained in this work are in line with those of RODRÍGUEZ-CLIMENT *et al*. (2012), which also indicated the normal scale model as the best fit for species with nearly fusiform body shape, while for the species with globular bodies, other models (*e.g.* gamma, lognormal) performed better.

The normal distribution also appears as the best model for all species analyzed in this work, whose specimens were mostly retained in the wedged or gilled forms. Therefore, there is evidence in favor of the hypothesis that a symmetrical distribution such as the normal one is suitable for cases in which the preponderant forms of retention are wedged and gilled. These results are similar to those previously obtained for other species (SANTOS *et al*., 2003; ERZINI *et al*., 2003; RODRÍGUEZ-CLIMENT *et al*., 2012).

In most cases the gillnets are made with the main purpose of retaining the target fish in the "gilled" form. Thus, the choice of mesh size should be compatible with the lengths of the target specimens, in such a way as to have a high efficiency and retention ratio in the gilled form. The other forms of retention would be secondary, and even receive popular denominations (*e.g.*, wedged, snagged, entangled) that do not share the radical of the word "gilled." If the mesh is suitable for what is proposed there is a high percentage of gilled specimens and the catches are relatively high. Therefore, the results of this work indicate that the 30 mm mesh is aligned with the proposed fishing target *Opisthonema oglinum* (Clupeidae) - and possibly other small pelagics of the Engraulidae family - because the proportion of retained fish in the gilled form, and the quantities caught are high.

When the results of the three different mesh sizes are evaluated, there is also a positive correlation between the proportion of those retained in the gilled form and the total catch for all the main species analyzed. Changes in the size of the mesh that result in a decrease in the proportion of specimens retained in the gilled form (or an increase in the percentage of retention in the other forms) would lead to incompatibilities of the nets and lengths of the passive specimens that would be captured, with a consequent loss of efficiency and a decrease of quantities captured.

O. oglinum selectivity curves estimated for 40 and 50 mm meshes cover ranges of lengths for which no observations of captured fish are available. However, in the case of the 30 mm mesh, there are observations of specimens captured in virtually all length classes for which high retention is predicted with the estimated curve. In this sense, it is understood that the curve calculated for 30 mm is more reliable than those calculated for 40 and 50 mm, which are largely extrapolated.

The first maturity lengths estimated for the three species highlighted in the present study work were: 117 mm of standard length for *O. oglinum* (LINO, 2003), 151 mm (males) and 162 mm (females) of total length for *A. clupeoides* (CASELLES and ACERO, 1996), and a total length of 118 mm for *C. edentulus* (SOUZA-CONCEIÇÃO *et al*., 2005). If these estimates are considered as references, it is concluded that the catches in the SCS are mostly composed of young and immature individuals, independent of the species.

The catches of juvenile individuals are particularly significant in operations with a mesh size of 30 mm. Consequently, suggestions to prohibit the use of this net or even increase the mesh size, would be the most natural alternatives against the history of fishery management in the Brazil. One of the main reasons for this, according to KOLDING and VAN ZWIETEN (2011), is that the management focuses on size and age following largely the "Propagation Theory" in which it is assumed that fish from a stock should have a high probability of reaching the size for reproduction without interference from fishing. However, in systems based on this simplistic concept, it is often assumed that variations in survival rates of fish as a function of age would be similar to those of mammals and birds, which is not adequate (KOLDING and VAN ZWIETEN, 2011; CADDY, 2015). It is simplistic to see that the solution for management is the isolated action of promoting the use of fishing gear that does not penalize fractions of juveniles. This type of management has traditionally been adopted in several countries, especially where detailed quantitative data and analyses of stock assessments are not available.

In the case of *O. oglinum*, fishing with the 30 mm mesh in the SCC, there are a number of considerations to be contemplated in the decision-making process regarding "minimum sizes" and possible restrictions and modifications of mesh sizes in order to reduce the capture of juveniles and possibly increase that of adults. An increase in mesh size should result in a smooth deviation of the length structure of the catch toward larger specimens. Additionally, judging by the estimation obtained for the selectivity parameters of the smaller mesh nets (30 mm), it would still efficiently retain individuals larger than *O. oglinum*, if they were present in abundance in the area. There is evidence in this regard, since the 30 mm mesh (between the opposing stretched nodes) is also used in coastal marine areas in other states (*e.g.* Ceará) and results in increased catches of longer specimens (LESSA *et al*., 2009). Therefore, the small amount of larger fish caught in the SCC is not merely an effect of the selectivity of the 30 mm mesh, but to a large extent a consequence that the abundance of such lengths is low in the SCC.

In the SCC, the most effective net for capturing available specimens was 30 mm, while the performances of 40 and 50 mm gillnets are lower, especially for *O. oglinum* which is the main target of the fishery. The exclusive use of larger meshes (*e.g.* 50 mm) would hardly sustain the local traditional fishing of forage species, with regards to the quantities caught. The use of larger meshes should also be considered, because it may lead to a reduction in the captured juvenile ratios, but this effect would not be accentuated since the abundance of adults is very low in the SCC. Thus, regimental options for mesh size would face great resistance from the fishermen in the SCC due to impracticable fishing for *O. oglinum* because of a possible drop in yield.

It is also important to note that clupeid stocks usually have high intrinsic growth rates (*i.e.* "r" strategists), with high reproduction and little parental care. Thus, in most species of the family the natural mortalities are high, especially in the young stages (*e.g.* PANHWAR *et al*., 2013). The total absence of capture at this stage may result in loss of biomass available for high levels of natural mortality. In addition, the fisheries in which juveniles are the purposefully caught may have a sustainable production in cases where fishing mortalities are low for the breeding stock (CADDY, 2015; WOLFF *et al*., 2015), since older fish have a greater contribution to reproduction than mature fish, due to higher fecundity and quality of spawning (HIXON *et al*., 2014). All these issues and possibilities should be considered for management measures that interfere with the selectiveness of gear that have traditionally been used for many years. In the case of *O. oglinum* fishing in the SCC, it is clear that the decision-making process would benefit greatly from studies of the natural and fishing mortality rates for juvenile forms, as well as indices of temporal changes in recruitment rates.

In addition to the provision of information, it is also evident in the SCC that proposals for modifying mesh size (*e.g.* increase) should be discussed widely and appropriately, including discussions with fishermen on alternatives facing the potential positive and negative consequences. If this process of understanding is not successful, it is difficult to implement management measures in artisanal fisheries, which are often not monitored and inspected. For example, KOLDING and VAN ZWIETEN (2011) observed that most small-scale fishers operating in African lakes would not follow the regimental suggestions of increasing mesh-size. It is hoped that scenarios such as these, where management measures are not effectively implemented, would not occur in the SCC which has a great importance and tradition in the fishing of forage species.

CONCLUSIONS

Catches with gillnets are multi-species in the SCC, even in the fisheries directed solely at *O. oglinum* carried out with a 30 mm mesh net. Catches of the main species of small pelagic fish were mostly composed of immature specimens. The density of larger individuals and adults is low in SCC. Increasing mesh size as a management alternative should be carefully evaluated, for it should not slightly decrease the proportion of juveniles in the catches, and it may also result in making it impossible for the fishery to continue with the reduced production.

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REFERÊNCIAS

ANDRADE, H.A.; SILVA, R.M.M. 2013 Dinâmica das frotas de pesca de emalhe e linha de mão de Itapissuma – PE no Canal de Santa Cruz. *Boletim Técnico Científico do Cepene*, *19*(1): 83-91.

BARRETO, C.F.; SANTANA-BARRETO, M.S. 1980 Deslocamento da Sardinha-Bandeira (*Opisthonema oglinum*, Lê Sueur, 1818) no Canal de Santa Cruz, Itamaracá – Pernambuco. *Anais da Universidade Federal Rural de Pernambuco*, *5*(1): 53-60.

BEVERTON, R.J.H.; HOLT, S.J. 1957 *On the dynamics of exploited fish populations: fishery investigations*. London: H.M. Stationery Off. 533p.

CADDY, J.F. 2015 Criteria for sustainable fisheries on juveniles illustrated for Mediterranean hake: control the juvenile harvest, and safeguard spawning refugia to rebuild population fecundity. *Scientia Marina*, *79*(3): 287-299. **http://dx.doi.org/10.3989/scimar.04230.06A**.

CAMPOS, A.; FONSECA, P. 2003 Selectivity of diamond and square mesh cod ends for horse mackerel (*Trachurus trachurus*), European hake (*Merluccius merluccius*) and axillary seabream (*Pagellus acarne*) in the shallow groundfish assemblage off the south-west coast of Portugal. *Scientia Marina*, *67*(2): 249-260. **http://dx.doi.org/10.3989/scimar.2003.67n2249**.

CARPENTER, K.E. 2002a *The living marine resources of the Western Central Atlantic. II (Acipenseridae to Grammatidae)*. Rome: Food and Agriculture Organization of the United Nations. p. 601-1374.

CARPENTER, K.E. 2002b *The living marine resources of the Western Central Atlantic. III (Opistognathidae to Molidae)*. Rome: Food and Agriculture Organization of the United Nations. p. 1375-2127.

CASELLES, O.A.; ACERO, P.A. 1996 Reproducción de *Anchovia clupeiodes* y *Anchovia parva* (Pisces: Engraulidae) en dos ciénagas del Caribe colombiano. *Revista de Biología Tropical*, *44*(2): 781-793.

ERZINI, K.; GONÇALVES, J.M.S.; BENTES, L.; LINO, P.G.; RIBEIRO, J.; STERGIOU, K.I. 2003 Quantifying the roles of competing static gears: comparative selectivity of longlines and monofilament gill nets in a multi-species fishery of the Algarve (southern Portugal). *Scientia Marina*, *67*(3): 341-352. **http://dx.doi.org/10.3989/scimar.2003.67n3341**.

FIGUEIREDO, J.L.; MENEZES, N. 1978 *Manual de peixes marinhos do sudeste do Brasil. II Teleostei (1)*. São Paulo: Museu de Zoologia da Universidade de São Paulo. 110p.

FIGUEIREDO, J.L.; MENEZES, N.A. 1980 *Manual de peixes marinhos do sudeste do Brasil. III Teleostei (2)*. São Paulo: Museu de Zoologia da Universidade de São Paulo. 98p.

FROESE, R. 2004 Keep it simple: three indicators to deal with overfishing. *Fish and Fisheries*, *5*(1): 86-91. **http://dx.doi.org/10.1111/j.1467-2979.2004.00144.x**.

GARCIA, S.M.; KOLDING, J.; RICE, J.; ROCHET, M.J.; ZHOU, S.; ARIMOTO, T.; BEYER, J.E.; BORGES, L.; BUNDY, A.; DUNN, D.; FULTON, E.A.; HALL, M.; HEINO, M.; LAW, R.; MAKINO, M.; RIJNSDORP, A.D.; SIMARD, F.; SMITH, A.D. 2012 Reconsidering the consequences of selective fisheries. *Science*, *335*(6072): 1045-1047. **http://dx.doi.org/10.1126/science.1214594**. PMid:22383833.

HIXON, M.A.; JOHNSON, D.W.; SOGARD, S.M. 2014 BOFFFFs: on the importance of conserving old-growth age structure in fishery populations. *ICES Journal of Marine Science*, *71*(8): 2171-2185. **http://dx.doi.org/10.1093/icesjms/fst200**.

HOVGÅRD, H.; LASSEN, H.; MADSEN, N.; POULSEN, T.M.; WILEMAN, D. 1999 Gillnet selectivity for North Sea Atlantic cod (*Gadus morhua*): Model ambiguity and data quality are related. *Canadian Journal of Fisheries and Aquatic Sciences*, *56*(7): 1307-1316. **http://dx.doi.org/10.1139/f99-070**.

IBAMA – INSTITUTO BRASILEIRO DO MEIO AMBIENTE E DOS RECURSOS NATURAIS RENOVÁVEIS, CEPENE – CENTRO NACIONAL DE PESQUISA E CONSERVAÇÃO DA BIODIVERSIDADE MARINHA DO NORDESTE, 2008 *Boletim estatístico da pesca marítima estuarina do nordeste do Brasil: 2006*. Tamandaré:IBAMA. 385p.

KARLSEN, L.; BJARNASON, B.A. 1987 *Small-scall fishing with driftnets*. Rome: Food and Agriculture Organization of the United Nations. 64p. (FAO Fisheries Technical Paper).

KOLDING, J.; VAN ZWIETEN, P.A.M. 2011 The tragedy of our legacy: How do global management discourses affect small scale fisheries in the south? *Forum for Development Studies*, *38*(3): 267-297. **http://dx.doi.org/10.1080/08039410.2011.577798**.

LAW, R.; PLANK, M.J.; KOLDING, J. 2012 On balanced exploitation of marine ecosystems: results from dynamic size spectra. *ICES Journal of Marine Science*, *69*(4): 602-614. **http://dx.doi.org/10.1093/icesjms/fss031**.

LESSA, R.; DUARTE-NETO, P.; MORIZE, E.; MACIEL, R. 2008 Otolith microstructure analysis with OTC validation confirms age overestimation in Atlantic thread herring *Opisthonema oglinum* from north-eastern Brazil. *Journal of Fish Biology*, *73*(7): 1690-1700. **http://dx.doi.org/10.1111/j.1095-8649.2008.02043.x**.

LESSA, R.; BEZERRA JUNIOR , J.L.; NÓBREGA, M.F. 2009 *Dinâmica de populações e avaliação dos estoques dos recursos pesqueiros da região nordeste*. Fortaleza: Editora Martins e Cordeiro. 304p. (Programa Revizee – Score Nordeste).

LINO, M.A.S. 2003 *Estudo biológico-pesqueiro da manjuba Opisthonema oglinum (Lesueur, 1818) da região de Itapissuma, Pernambuco*. Recife. 46p. (Dissertação de Mestrado. Pós-graduação em Recursos Pesqueiros e Aquicultura, UFRPE). Available from: <http://www.pgpa.ufrpe.br/Trabalhos/2003/R2003masl.pdf> Access on: 1 feb. 2015.

MAES, J.; OLLEVIER, F. 2002 Size structure and feeding dynamics in estuarine clupeoid fish schools: field evidence for the school trap hypothesis. *Aquatic Living Resources*, *15*(4): 211-216. **http://dx.doi.org/10.1016/S0990-7440(02)01181-6**.

MEDEIROS, C.; KJERFVE, B. 1993 Hydrology of a tropical estuarine system: Itamaracá, Brazil. *Estuarine, Coastal and Shelf Science*, *36*(5): 495-515. **http://dx.doi.org/10.1006/ecss.1993.1030**.

MENEZES, N.A.; FIGUEIREDO, J.L. 1980 *Manual de peixes marinhos do sudeste do Brasil. IV. Teleostei (3)*. São Paulo: Museu de Zoologia da Universidade de São Paulo. 96p.

MENEZES, N.A.; FIGUEIREDO, J.L. 1985 *Manual de peixes marinhos do sudeste do Brasil. V. Teleostei (4)*. São Paulo: Museu de Zoologia da Universidade de São Paulo. 105p.

MILLAR, R.B. 1992 Estimating the size-selectivity of fishing gear by conditioning on the total catch. *Journal of the American Statistical Association*, *87*(420): 962-968. **http://dx.doi.org/10.1080/01621459.1992.10476250**.

MILLAR, R.B.; FRYER, R.J. 1999 Estimating the size-selection curves of towed gears, traps, nets and hooks. *Reviews in Fish Biology and Fisheries*, *9*(1): 89-116. **http://dx.doi.org/10.1023/A:1008838220001**.

MILLAR, R.B.; HOLST, R. 1997 Estimation of gillnet and hook selectivity using log-linear models. *ICES Journal of Marine Science*, *54*(3): 471-477. **http://dx.doi.org/10.1006/jmsc.1996.0196**.

MOURA, R.T. 2009 *Aspectos gerais da hidrobiologia do litoral norte de Pernambuco, Brasil*. Brasília: IBAMA. 138 p.

PANHWAR, S.K.; LIU, Q.; SIDDIQUI, G. 2013 Growth, Mortality and Stock Assessment of Kelee Shad, *Hilsa kelee* (Fam: Clupeidae) in the Coastal Waters of Pakistan. *Journal of Ichthyology*, *53*(5): 365-371. **http://dx.doi.org/10.1134/S0032945213030168**.

R CORE TEAM 2017 *R: a Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing. Available from: <https://www.R-project.org/>. Access on: 1 feb. 2015.

REGIER, H.A.; ROBSON, D.S. 1966 Selectivity of gill nets, especially to Lake whitefish. *Journal of the Fisheries Research Board of Canada*, *23*(3): 423-454. **http://dx.doi.org/10.1139/f66-034**.

REIS, E.G.; PAWSON, M.G. 1999 Fish morphology and estimating selectivity by gillnets. *Fisheries Research*, *39*(3): 263-273. **http://dx.doi.org/10.1016/S0165-7836(98)00199-4**.

RODRÍGUEZ-CLIMENT, S.; ALCARAZ, C.; CAIOLA, N.; IBÁÑEZ, C.; NEBRA, A.; MUÑOZ-CAMARILLO, G.; CASALS, F.; VINYOLES, D.; SOSTOA, A. 2012 Gillnet selectivity in the Ebro Delta coastal lagoons and its implication for the fishery management of the sand smelt, *Atherina boyeri* (Actinopterygii:Atherinidae). *Estuarine, Coastal and Shelf Science*, *114*(17): 41-49. **http://dx.doi.org/10.1016/j.ecss.2011.09.008**.

SANTOS, M.N.; GASPAR, M.; MONTEIRO, C.C.; ERZINI, K. 2003 Gill net selectivity for European hake *Merluccius merluccius* from southern Portugal: implications for fishery management. *Fisheries Science*, *69*(5): 873-882. **http://dx.doi.org/10.1046/j.1444-2906.2003.00702.x**.

SOUZA-CONCEIÇÃO, J.M.; RODRIGUES-RIBEIRO, M.; CASTRO-SILVA, M.A. 2005 Dinâmica populacional, biologia reprodutiva e o ictioplâncton de *Cetengraulis edentulus* Cuvier (Pisces, Clupeiformes, Engraulidae) na enseada do Saco dos Limões, Florianópolis, Santa Catarina, Brasil. *Revista Brasileira de Zoologia*, *22*(4): 953-961. **http://dx.doi.org/10.1590/S0101-81752005000400023**.

SPARRE, P.; VENEMA, S.C. 1997 *Introdução à avaliação de mananciais de peixes tropicais. Parte l: manual*. Rome: Food and Agriculture Organization of the United Nations. 404p.

STEWART, J. 2008 A decision support system for setting legal minimum lengths of fish. *Fisheries Management and Ecology*, *15*(4): 291-301. **http://dx.doi.org/10.1111/j.1365-2400.2008.00614.x**.

TACON, A.G.J.; METIAN, M. 2009 Fishing for feed or fishing for food: increasing global competition for small pelagic forage fish. *Ambio*, *38*(6): 294-302. **http://dx.doi.org/10.1579/08-A-574.1**. PMid:19860152.

WOLFF, M.; TAYLOR, M.H.; TESFAYE, G. 2015 Implications of using small meshed gillnets for the sustainability of fish populations: a theoretical exploration based on three case studies. *Fisheries Management and Ecology*, *22*(5): 379-387. **http://dx.doi.org/10.1111/fme.12137**.